Volume 5 JUNE 9, 1930 Number 4

# BULLETIN

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OF THE

## AMERICAN PHYSICAL SOCIETY

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PROGRAM OF THE

## ITHACA MEETING

AT

## CORNELL UNIVERSITY

JUNE 19–21, 1930

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PUBLISHED BY THE AMERICAN PHYSICAL SOCIETY
SEVEN ISSUES EACH YEAR

# The American Physical Society

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Volume 5 JUNE 9, 1930 Number 4

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of the

AMERICAN PHYSICAL SOCIETY

Published seven times per year

Subscription price: $1.00 per year.

The Bulletin of the American Physical Society is published seven times a year during the months of February, April, June (2 issues), November (2 issues), and December at 450 Ahnaip Street, Menasha, Wisconsin.

Entered at the post office at Menasha, Wisconsin, as second class matter.

JUNE 9, 1930 Vol. 5, No. 4

# BULLETIN

OF THE

# AMERICAN PHYSICAL SOCIETY

## ITHACA MEETING, JUNE 18–21, 1930

*The program will follow Eastern Standard Time*

The 165th meeting of the American Physical Society will be held in Ithaca, N. Y. on Thursday, Friday and Saturday, June 19, 20 and 21.

All scientific meetings in Ithaca will be held in Rockefeller Hall. The first session will begin at 10 o'clock Thursday morning, June 19. Titles and abstracts of the papers to be presented at this session are given in the following pages. These abstracts have not been corrected by the authors. After correction they will be published in an early number of the Physical Review. Authors should send corrections to the Editor of the Physical Review at the University of Minnesota, Minneapolis, Minnesota.

*Registration will begin at 8:30 Thursday morning in the Rockefeller Hall Library. The council of the Society has authorized a Registration fee of $1.00 for each physicist attending this meeting.*

At this registration one will have an opportunity to register his car and trip mileage, to make arrangments for playing golf and tennis, to sign up for the men's bathing beauty contest, to secure tickets for the picnic, and to learn about the time and place for informal conferences.

## WEDNESDAY, JUNE 18

**Visit to Corning Glass Works.** On Wednesday, June 18, the day before the Ithaca program begins, the Corning Glass Works will entertain those attending this meeting at a 12 o'clock luncheon to be held at the Hotel Baron Steuben, Corning, N. Y. Following the luncheon the party will be taken on an inspection trip through the Glass Works. Corning may be reached by the main line of the Erie or Lackawanna Railroad. It is also on main automobile routes through Geneva, Mount Morris, Hornell, Binghamton, and Williamsport, (Pa.). (Automobiles from Ithaca will leave Rockefeller Hall at 10:00). At about 4:30 the group will leave Corning by automobile for Ithaca (45 miles), arriving in Ithaca in time for dinner at 6:30.

Members motoring from points south and west may wish to visit the Wellsboro (Pa.) lamp factory of the Corning Glass Works en route. Here the latest type of fully automatic bulb blowing machinery will be demonstrated. Wellsboro is on the Roosevelt Highway, 12 miles west of Mansfield which is on the Susquehanna trail. The Wellsboro Plant is on the eastern outskirts of Wellsboro as approached from Mansfield, and is 42 miles south of Corning. Comfortable accommodations are available in Wellsboro at the Penn-Wells.

It might be practicable to arrive in Wellsboro Tuesday night or early Wednesday morning. This lamp factory could then be visited and the trip continued in time to reach Corning for lunch. Members arriving in Corning early Wednesday morning could visit the Corning (main)

plant that morning and the Wellsboro plant in the afternoon, or vice versa, as best suited their convenience.

For further information, address Dr. J. T. Littleton, Corning Glass Works, Corning, N. Y.

**Entertainment.** On Thursday afternoon a picnic will be held at upper Enfield Glen, located about five miles from Ithaca. Tickets for the picnic should be obtained at the registration desk, Rockefeller Hall Library, before 1 o'clock Thursday afternoon by everyone planning to attend. For those not having reservations in Risley Hall, a fee of $1.00 will be charged for this picnic. The group should plan to leave the Campus for the picnic about 4:00 P.M. or at such times as may be announced on the bulletin board. In case of bad weather the picnic will be held in Risley Hall.

Ladies are invited to attend an informal bridge party in the Risley Hall Drawing Rooms, beginning at 10 o'clock Friday morning.

*Professor V. Karapetoff* will give a panio recital with demonstration of Theremin and five-string cello, in the Risley Hall Recreation room, at 5 o'clock Friday afternoon.

Following dinner on Friday evening an informal assembly will be held at Risley Hall. For those not having dinner at Risley Hall, it is announced that the assembly will begin about 8 o'clock.

On Saturday evening at about 8 o'clock a final get-together will be held at a place to be announced later. Various prizes will be awarded and you will have a chance to complete some of the visiting you wanted to do.

Informal dress at all functions will be in order.

**Sports.** Those wishing to play golf may obtain guest cards, entitling the holder to the privileges of the Ithaca Country Club, upon payment of the usual greens fee. Those wishing to play tennis will find numerous courts available. A tennis tournament will be staged for the three day period. Those wishing to enter this tournament should so indicate on the **return card** (sent to members in April) and come prepared to play preliminary matches on the first day. Finals will be played off Saturday afternoon.

A swimming pool near the Campus will be available at all times. Bring your bathing suit and raincoat and be prepared to enter the men's bathing beauty contest at 5:30 o'clock Friday afternoon.

More complete information regarding sports will be available at the registration desk in Rockefeller Hall.

**Accommodations.** Up to the limit of its capacity, Risley Hall, one of the University Residential Halls for women, will be used for housing members and their guests, including ladies. It will be the center of social activities throughout the meeting. Accommodations in Risley Hall will be available beginning with dinner Wednesday evening and ending with breakfast Sunday morning; rate $5.00 per day, American plan. Requests for reservations, on **return card**, (sent to members in April), should reach Ithaca not later than June 7.

Those who may prefer accommodations in a hotel should write directly to the hotel. Hotel rates, European plan: Ithaca Hotel, $4.00 per day with bath and up. Clinton House, without bath, single $2.50, double $4.00; with bath, single $3.50, double $7.00. Hotels are about twenty minutes from Campus by street car. In as much as there will be at least two other conventions of equal size in Ithaca during these same three days, it is highly desirable that all reservations be made promptly.

In addition to those having rooms in Risley Hall, a limited number may obtain meals there. Applications for such meals should be made at the registration desk in Rockefeller Hall at least 2 hours before the meal.

**Railroads.** Ithaca may be reached by the Lehigh Valley or the Lackawanna Railroad. All trolley cars from Ithaca stations pass Rockefeller Hall and Risley Hall; trolley from East Ithaca has been discontinued.

**Automobile.** Ithaca is situated in the beautiful Finger Lakes Region of Central New York in which there are five state parks within easy reach of Ithaca and the highest waterfall (Taugh-

annock) east of the Rockies. Approach from every direction is picturesque, whether through the Catskill Mountains or the mountains of Pennsylvania (via Binghamton or Elmira), over famous New England trails (via Albany and Cortland or Binghamton), or over transcontinental routes from the West (via Geneva or Corning.) **Come by auto** and bring your family. Write to the Ithaca Chamber of Commerce for the Finger Lakes booklet and Ithaca leaflet.

A prize will be awarded the automobile coming the longest distance and registering by 10 o'clock Thursday morning, with handicap for later registration up to noon. (This handicap does not apply to cars coming from west of the Rockies or east of the Penobscot River.) Prizes will also be awarded the newest car and the oldest car, as indicated by total mileage on registering and to the oldest car, judged at the picnic by vintage and visual evidence of decrepitude, local cars not included.

Two very scenic places that you may wish to visit while in Ithaca are Taughannock Falls on the west side of Cayuga Lake about 10 miles from Ithaca, and Watkins Glen at the south end of Seneca Lake about 28 miles from Ithaca.

**Automobile parking.** Day parking in reserved area southwest of Bailey Hall. (Follow signs from Rockefeller Hall.) Night parking back of faculty apartments opposite Risley Hall, or, if preferred, in garage downtown. (There are no garages convenient to Risley Hall.)

Other meetings for the current season are as follows:
164. June 18–21, 1930. Pacific Coast, Eugene, Oregon.
166. November 28–29, 1930. Chicago.
167. December, 1930. (Exact date not yet determined.) Pacific Coast, Los Angeles.
168. Annual Meeting, Cleveland, December 30–31, 1930.

*CALENDAR*

| | | |
|---|---|---|
| Wednesday, June 18: | 10:00 | Cars from Ithaca leave Rockefeller Hall for Corning. |
| | 12:00 | Lunch, as guests of Corning Glass Works. |
| | 2–4:00 | Inspection Corning Glass Works. (See more detailed announcements in previous paragraphs.) |
| | 4:30 | Leave for Ithaca. |
| | 6:30 | Dinner at Risley Hall. |
| Thursday Morning, June 19: | 8:30 | Registration opens; Rockefeller Hall Library. |
| | 10:00 | Contributed papers; Rockefeller Hall. Lecture Room A: Papers 1–15. Lecture Room B: Papers 16–30. The supplementary program beginning with No. 31 may be called for at the end of the session in Lecture Room A. See pages 12–45 for titles and abstracts. |
| Thursday Afternoon, June 19: | 2:00 | Informal Conferences, Sports. See bulletin board for detailed announcements. |
| | 4:00 | Leave Rockefeller Hall or Risley Hall for picnic at upper Enfield Glen. (In |

case of bad weather picnic will be held in Risley Hall.)

6:00 Picnic dinner.

**Friday Morning, June 20:** 10:00 Rockefeller Hall, Lecture Room A; Papers on Astrophysics.

*S. A. Mitchell*, Director, McCormick Observatory, University of Virginia, "Atomic Structure under Conditions of Temperature and Pressure Found at the Sun's Surface."

*J. Q. Stewart*, Princeton University Observatory, "The General Problems of Astrophysics with Special Reference to the Opacity of Gases."

12:30 Luncheon.

**Friday Afternoon, June 20:** 2:00 Rockefeller Hall, Lecture Room A. Address by Sir William Bragg, "Faraday's Diary."

3:30–6:00 Informal conference and sports. (See bulletin board for details.) Men's Bathing Contest at 5:30, Beebe Lake.

5:00 Piano Recital with demonstration of Theremin and five-string Cello, by Professor Karapetoff, Recreation Room, Risley Hall.

6:30 Dinner.

8–10:00 Informal Assembly, Risley Hall.

**Saturday Morning, June 21:** 10:00 Rockefeller Hall, Lecture Room A. Invited paper.

*F. Zwicky*, "Secondary Structure of Crystals."

*R. W. Wood*, "Improvements in Technique in the Study of the Raman Effect with Particular Reference to Excitation by Single Lines."

*Arthur H. Compton*, "X-Ray Scattering and Atomic Structure."

12:30 Luncheon.

**Saturday Afternoon, June 21:** 2–6:00 Informal conferences and sports, (See bulletin board for details); tennis finals, 2:00; swimming, 5:30.

8:00 Final get-together with award of prizes. (Place to be announced.)

**(NOTE: Risley Hall will be open until after breakfast Sunday.)**

W. L. SEVERINGHAUS, *Secretary*

**June 9, 1930.** Columbia University, New York City.

## THURSDAY MORNING AT 10 O'CLOCK

### Lecture Room A

**1. A new type of glow-discharge tube.** HERBERT J. REICH, *University of Illinois.*—Several types of glow-discharge tubes are somewhat limited in their field of usefulness by the fact that the extinction potential is considerably lower than the ignition potential, making it difficult to control or stop the current after discharge commences. This difficulty may be overcome by incorporating an electron gun in the tube, and shooting a stream of electrons at high velocity between or through the glow electrodes. The discharge may thus be completely controlled at all times by a very small variation in the potential of the control electrode of the electron gun. A study of the characteristic curves of such a tube reveals a number of very interesting operating characteristics.

**2. Preliminary measurements of the mean free path of potassium atoms in nitrogen.** J. J. WEIGLE AND M. S. PLEASANT, *University of Pittsburgh.*—The method of Taylor (Zeits. f. Physik **57,** 242 (1929)) for the detection of beams of potassium atoms was used for a direct determination of their mean free path. A steel furnace with a single slit contained the potassium and was heated to about 150°C. At a distance of 10 cm a tungsten filament parallel to the slit, and surrounded by a slotted brass cylinder was used as a detector. The potassium atoms impinging on the hot filament are ionized and drawn to the cylinder by a suitable difference of potential. This positive ion current was measured as a function of the pressure of nitrogen filling the space between the filament and slit. Nitrogen pressures ranged from $10^{-2}$ to $10^{-5}$ cm of mercury. These ion currents are given by the equation $I = I_0 e^{-x/\lambda(p)}$ where $I_0$ is a constant, $\lambda(p)$ the mean free path at a given pressure $p$, and $x$ the distance between the slit and filament. As $\lambda$ is a known function of the average of the diameters of the potassium atom and nitrogen molecule, this average was obtained from our measurements which gave values between $3\times10^{-9}$ and $5\times10^{-9}$ cm. These results are unexpectedly small. Experiments with a different apparatus are contemplated to disprove or confirm these preliminary results.

**3. Organic reactions in gaseous electrical discharge.** ERNEST G. LINDER, *Cornell University.*—A study of electrical discharge in a series of straight chain paraffin hydrocarbons indicates that the phenomenon is similar to that of electrolytic conduction in liquids, in so far as the amount of reaction (i.e., the amount of hydrogen liberated) appears to be proportional to the current, and independent of vapor pressure and voltage. There seems to be a simple relation between molecular size and the amount of hydrogen liberated.

**4. On the recombination of electrons with caesium ions.** E. H. KURTH, *California Institute of Technology.* (*Introduced by F. Zwicky.*)—An apparatus was constructed in which electrons emitted from a caesium-on-tungsten oxide surface could be accelerated into an equipotential inclosure. A beam of caesium ions generated by a tungsten filament source and projected through the electron atmosphere in the box was collected on a plate. Electron currents up to 200 microamperes could be obtained with a few volts potential difference to the box. Positive currents were measured down to $10^{-9}$ amperes. When the electron velocities were varied over the range in which captures by caesium ions might be expected from the work of Davis and Barnes, no measureable decrease in the positive beam current was ever observed. The apparatus is being modified to permit tests for a considerably greater ratio of electron to positive currents.

**5. Potential drop-current relations of a geissler discharge from a hollow cathode.** C. H. THOMAS, *Westinghouse Lamp Co., Bloomfield, N. J.*—When a cold electrode, drilled to a depth 1/2 inch with a drill 0.076 inch in diameter was used as a cathode in neon gas at pressures between 5 and 70 mm with electrode separation of 15 mm the cathode glow concentrated almost entirely in the hole. Under these conditions the potential drop-current curve for a thorium cathode shows a maximum in potential drop at a current of about 25 milliamperes. This potential drop decreases to a minimum at 50 milliamperes and subsequently attains a second maximum at 80–90 milliamperes. At a higher current a further decrease in potential drop resulted from thermionic emission. Similar curves for iron, misch metal and thorium-barium

oxide cathodes in neon show a maximum at about 25 milliamperes but beyond that current their similarity to thorium curves disappears. Similar effects were observed in helium and argon. Potential drop-pressure curves for a cathode drilled with a 0.076 inch hole are given as well as the potential drop-size of hole curves which show that there is a minimum pressure for a given size hole in order that the cathode glow will concentrate in the hole. A hollow iron cathode in hydrogen at 23 mm pressure caused a decrease in the potential drop from 440 volts to 405 volts as the current was increased from 30 to 50 milliamperes.

**6. The electrodeless discharge in mercury vapor.** HERSCHEL SMITH, W. A. LYNCH AND NORMAN HILBERRY, *New York University, University Heights.*—The electrodeless discharge produced in Hg vapor inside the solenoid of a high frequency C. W. oscillator is studied in the pressure range between 0.004 mm and 0.8 mm of Hg. The characteristics of the two types of discharges reported by various authors (MacKinnon, Phil. Mag. Nov. 1929; Brasefield, Phys. Rev. May. 1930) are investigated in detail. Direct experimental evidence is given as to the electrostatic nature of the "glow" discharge and to the electromagnetic nature of the "arc" type discharge. Electromagnetic forces in themselves are found to be insufficient for the formation of the discharge but are sufficient for its maintenance. The "arc" type discharge is shown to be the more familiar ring discharge excited by damped oscillations. The currents in the oscillator coil necessary for the excitation of both types of discharge are examined as a function of the pressure at various frequencies. The curve for the glow discharge has a minimum within the given pressure range while that of the "arc" type discharge has both a minimum and a maximum. The form of these curves would seem to indicate the necessity for a complete revision of the present theories.

**7. Effect of collisions on potential distribution in positive ion sheaths.** H. P. ROBERTSON AND P. M. MORSE, *Princeton University.*—The potential distribution in a plane positive ion sheath is derived under the assumptions (1) an ion gives up a fraction $\theta$ of its kinetic energy at each collision, (2) the ions may be considered as following the lines of force and (3) the density of charge may be taken as $i/v$ where $v$ is the root mean square of the actual ionic velocities. The justification of assumption (2) is based on the considerations of v. Hippel, and that of (3) on the approximate agreement of dependence of potential on initial velocity for zero pressure with that obtained by previous workers (Schottky, Epstein, Fry, Langmuir). The rigorous solution of this problem gives the field strength and mean forward kinetic energy of the ions at any point in the sheath. The corresponding problem for cylindrical or spherical cathodes cannot be rigorously solved by the same methods, but can be treated by a method of approximations based on the rigorous solution for the plane case.

**8. The Hall effect in tellurium amalgams.** P. I. WOLD AND J. M. HYATT, *Union College.*—Certain aspects of the study of the Hall effect in crystalline materials suggested an attempt to make Te-Hg alloys. Amalgams were obtained of about 30% tellurium which were plastic when fresh but which became, in a few hours, quite hard and very friable. The plastic amalgam was placed in a mold as quickly as feasible and measurements on the Hall effect, the specific resistance and the longitudinal effect were started. The Hall effect commenced with very small values and built up steadily for two or three days. The Hall constants, after such time, were as high as 0.9, which is from 100 to 500 times the value when the amalgam was a half hour old. The authors are not aware of any previous case in which Hall effect has grown with time when temperature was constant and as a new phenomenon it seems to be of special interest. X-ray crystal photographs were taken of a sample of the amalgam as soon after making as possible and photographs taken within an hour show crystalline structure apparently as strongly as when two days old. The longitudinal effect started with very low values and increased steadily in about the same way as the Hall effect.

**9. Contact resistance and microphonic action.** FRANK GRAY, *Bell Telephone Laboratories, Inc.*—A mathematical theory is developed to explain the fact that conductivity of a contact between two carbon spheres changes with the force pressing the spheres together. It is assumed that the surface roughness of the carbon is equivalent to an assembly of minute spherical hills.

On account of the elasticity of the material, both the macroscopic area of contact between the spheres and the microscopic areas of contact between the hills increase with contact force. The resulting relation between the contact resistance $R$ and the contact force $F$ is $R=A/F^{1/3}+B/F^{7/9}$ where $A$ and $B$ are constants. The last term of this equation, contributed by surface roughness, is almost the same as the corresponding term of the equation, $R=A/F^{1/3}+B/F^{6/9}$ which was developed by Professor P. O. Pedersen [Electrician, Feb. 4, 1916] on the assumption that carbon is covered with a thin, high resistance film. In other words, surface roughness behaves almost identically with a non-variable, high resistance film. Higher degrees of roughness increase the exponent of the last term. In the limit it becomes unity, and the roughness resistance then varies inversely as the contact force.

**10. Contact resistance and microphonic action.** F. S. GOUCHER, *Bell Telephone Laboratories, Inc.*—Previous work has shown that the conducting portions of contacts between single granules of microphone carbon are of the nature of carbon and that variations in contact area occur when the contact resistance is varied in a reversible resistance force cycle. An experimental study of the slopes of these reversible characteristics both for single contacts and aggregates shows them to be of the form $R=\text{const}(F)^{-n}$. The exponent $n$ varies from cycle to cycle for equal force limits and the average value depends on the force limits. A maximum mean value independent of the force limits over a wide range, is obtained with the aggregates. This value is in agreement with the exponent in the second term of Gray's equation $R=(A/F^{1/3})+(B/F^{7/9})$ [previous abstract] which indicates that an aggregate of contacts may, under certain conditions, behave as though it were a single contact between spheres having a rough surface. Values of $n$ less than 1/3 are obtained with both single contacts and aggregates. This is attributed to the effect of cohesive forces the existence of which was demonstrated by the sticking of contacts.

**11. Work function and thermionic and constant "A" determined for thoriated tungsten.** W. B. NOTTINGHAM, *Bartol Research Foundation.*—The work function of a type $T$ thoriated tungsten filament was determined with a 3.5 volt accelerating potential by measuring the thermionic current as a function of temperature over the range 1045°K to 1340°K. With the filament activated to give the maximum emission at 1100°K with a 20 volt accelerating potential, the effective work function $\phi^1$ with 3.5 volts was found to be 2.59 volts. From measurements of the current-potential relationship at 1100°K, it was found that the 3.5 volt accelerating potential had reduced the work function by $\Delta\phi=0.56$ volt. The work function at *zero field* is $\phi^1+\Delta\phi=\phi_0=3.15$ volts. Using this value of $\phi_0$ and the measured current, the thermionic constant is $A=59.0$. Measurements made with a thorium covering *thicker* than that required to give the maximum emission as above, gave $\phi^1=2.8$ volts with 3.5 volts accelerating potential; $\Delta\phi=0.3$ volt and therefore $\phi_0=3.1$ volts and $A=56.0$. These data indicate that abnormally low values of $A$ previously reported can be accounted for by the fact that the work functions were not measured at zero field. Langmuir found the contact potential between thoriated tungsten and clean tungsten to be 1.46 volts. Accordingly the work function of thoriated tungsten should be $4.53-1.46=3.07$ volts which agrees with the above.

**12. The relation between the number of electrons ejected photoelectrically from the cathode and the time lag of the spark.** JOHN A. TIEDEMAN, *University of Virginia.* If the ions usually present in a spark gap in ordinary air are carefully removed by sweeping potentials an impulsive field of 75,000 volts/cm can be applied for at least $10^{-6}$ sec. without electrical breakdown. Strong ultraviolet irradiation of the cathode reduces the time lag to less than $10^{-8}$ sec. By means of biasing potentials and a steady source of ultraviolet light electrons could be liberated from the cathode only during the existence of a high electric field. The time lags were measured by the Lichtenberg figure method (Pedersen, Ann. d. Physik **71**, 317 (1923)). By controlling the intensity of ultraviolet light on the cathode and the magnitude of the applied surge potential the time required for a known number of electrons to start the discharge in a field of known strength could be obtained. Between a Zn cathode and a steel anode spaced 2 mm electrons were ejected from the cathode at the rate of one in $3.3\times10^{-9}$ sec. in an impulsive field with a maximum value of 75,000 volts/cm applied by a second spark, producing a time lag of $1.5\times10^{-8}$ sec. while under the same conditions one electron per $9.5\times10^{-9}$ sec. gave a time lag of $2.2\times10^{-8}$ sec.

**13. Inhibition of photoelectric emission by near infrared light.** A. R. OLPIN, *Bell Telephone Laboratories, Inc.*—The response of potassium photoelectric cells to white light is greatly increased when small amounts of bromine or iodine vapor are distilled onto the cathode surface. Spectral distribution curves for cells so treated show a general increase in the response to light of all wave-lengths and a more marked increase to light at both ends of the visible spectrum. There is no measurable electron emission when the cells are irradiated with infrared light obtained by passing white light of color temperature 2848°K. through a #87 EK Wratten filter. If, however, the cathode already is emitting electrons under excitation with visible light when irradiation with infrared light occurs, a marked *decrease* in the photoelectric current is noted. Investigation shows that this decrease occurs only in the spectral regions when abnormally large increases are observed without the infrared light, and may amount to well over fifty per-cent for certain wave-lengths. Data showing some of the properties of this new effect, which has been observed for both potassium and sodium cells, are included. The phenomenon is closely analogous to the extinction of phosphorescence and destruction of the latent image on photographic plates by infrared radiations.

**14. On chain reactions caused by physical structure.** N. RASHEVSKY, *Westinghouse E. and M. W., East Pittsburgh.*—In a previous paper (Zeits. f. Physik **59,** 558 (1930)) it has been shown that when a substance is formed as a result of a reaction in a solution and is itself soluble in the surrounding liquid, this substance may exist as a separate phase, in shape of small drops, provided the size of the drops is above a certain critical value. Such drops cannot be formed spontaneously, but will continue to grow if brought from outside into the liquid. In the present paper, the case is considered, that the drop is constituted of several substances. Due to the interaction of the phenomena of diffusion and dissolution, the formation of the different substances will follow a definite order. Below a certain size, the drop cannot exist at all. Above it, it can be constituted only by one substance. With increasing size, the number of substances constituting the drop, increases. Applications to biological phenomena are discussed.

**15. The corresponding state of maximum surface tension of saturated vapors.** J. L. SHERESHEFSKY, *Mellon Institute of Industrial Research. (Introduced by Paul D. Foote.).*—The surface tension of a liquid is given by the expression (1) $\sigma = (rh/2)(\rho_1 - \rho_2)$, where $h$ is the height of rise in a capillary of radius $r$, and $\rho_1$ and $\rho_2$ the densities of the liquid and vapor respectively. Writing the equation in the form $\sigma_r = rhe_1/2 - rhe_2/2$ and applying Antonow's rule, $rhe_1/2$ may be conceived as the true surface tension of the liquid, $\sigma_r$ the relative surface tension, and (2)$\sigma_r = rhe_2/2$ where $rhe_2/2$ is defined as the surface tension of the vapor. Combining (1), (2), McLeods equation $[\sigma_r = c(\rho_1 - \rho_2)^4]$ and Goldhammer's equation $[\rho_1 - \rho_2 = a(1 - T/T_c)^{1/3}]$, an expression is obtained relating the surface tension of the vapor with the temperature, (3) $\sigma_v = K(1 - T/T_c)\rho_2$. It was found that $\sigma_v$ goes through a maximum in the neighborhood of the critical temperature. Differentiating (3) the position of the maximum point is given by

$$\frac{d \log \rho_2}{dT} = \frac{0.4343}{T_c(1 - T_m/T_c)}. \tag{4}$$

By means of equation (4) the values of $T_m/T_c$ for nineteen different substances were calculated and found to equal 0.91.

## THURSDAY MORNING AT 10 O'CLOCK

### Lecture Room B

**16. Fundamental correspondences between geometry and thermodynamics.** JOHN Q. STEWART, *Princeton University.*—Continuing interpretation of thermodynamics as a physical symbolic logic (Phys. Rev. **34,** 1289, (1929), etc.), the following equivalences exist between Euclidean plane geometry and the thermodynamics of reversible systems having two degrees of freedom. The *vector* corresponds to the working body; its magnitude, $r$, to volume, $v$; $x$-component to internal energy, $U$; $y$-component to entropy, $S$; negative slope, $-m$, to temperature, $T$. Summing $x$ and $y$ components, respectively, when vectors are added, corresponds to con-

serving energy and entropy. The Pythagorean relation, $x=(r^2-y^2)^{\frac{1}{2}}$, expresses the "equation of state" for the Euclidean plane. The corresponding special thermodynamic equation $U=(v^2-S^2)^{\frac{1}{2}}$, implies reckoning $U$, $v$, $S$, in absolute units, for dimensional equivalence. In general, when $U_2$ replaces $S_1$, and $-S_2$ replaces $U_1$, while $v$ remains unchanged, $-1/T_2$ replaces $T_1$, and all relations of thermodynamics are preserved. This is one form of Lunn's important "principle of thermodynamic duality." (A. C. Lunn, Phys. Rev. **15**, 269 (1920)). Evidently it corresponds to the geometrical symmetry accompanying rotation of axes through $\pi/2$. The general background of these studies is the philosophy of Leibniz. His logic possesses surprisingly close affiliations with thermodynamics.

**17. Entropy, elastic strain and the second law of thermodynamics, the principles of least work and of maximum probability.** W. S. KIMBALL, *Michigan State College, East Lansing, Michigan.*—By relying on the geometrical expression for weight, $W=N^N(r_1r_2\cdots r_N)$, and taking strains to include unit extensions in velocity and momentum space as well as ordinary space, a relation is established between entropy and the total strain: $S=kY$; $Y=\log W$, where $S$ is the entropy, $k$ is Boltzmann's constant, $Y$ the total strain and $W$ the *apriori* probability. The Lagrange multiplier method is applied to statically indeterminate frames as well as gas theory, and shows in both cases that the principle of least work, or internal energy, is equivalent to the principle of maximum entropy, probability and strain. Furthermore the equilibrium equations which by the Lagrange method determine the equilibrium state are shown to represent balance between true stress and strain both in gas theory and in the statics of indeterminate frames, revealing the operation in these two domains of the same identical principles (not an analogy). The magnitude of the stress and strain acting in momentum space to maintain equilibrium are calculated for the case of perfect gas at temperature $T$, the stress being given by $(2\pi e)^{\frac{1}{2}}/kT$, and the strain by $(2\pi e)^{\frac{1}{2}}/n$, and the modulus of elasticity is the familiar isothermal bulk modulus $p$. The outstanding experimental verification of the theory is the second law of thermodynamics. The automatic increases of entropy which it represents are explained as due to increased strain (in momentum space as well as ordinary space) under action of corresponding stresses, rather than as in statistics by the unsatisfactory ergodic hypothesis.

**18. Energy changes related to the secondary structure of crystals.** F. ZWICKY, *California Inst. of Technology.*—Theoretical considerations have led the author to the postulate of a secondary structure (II) of large spacing, which is superposed on the primary structure ($p$) of crystals. According to the theory the II-atoms are usually more densely packed than the $p$-atoms. It is $|E_\pi|>|E_p|$ where $E_\pi$ and $E_p$ are the respective atomic energies corresponding to the two structures. The $p$-atoms are therefore more easily removed from the crystal than the II-atoms. Conditions may be reversed, however, by a plastic deformation inasmuch as this process diminishes $|E_\pi|$ into $|E_\pi'|$ but does not change $E_p$. These conclusions lead at once to an understanding of evaporation, etching and certain chemical reaction phenomena involving both perfect and plastically deformed crystals. As a practical criterion of the perfection or imperfection of a lattice the inequalities $|E_\pi'|\gtrless|E_p|$ may be used. More detailed considerations are of course required to distinguish crystals of the "metallic" type, which are both macroscopically and microscopically plastic from other types like NaCl which are macroscopically plastic but microscopically brittle. The theory further leads to the interesting conclusion that a voltaic potential difference should be found between II-planes and $p$-planes a mounting in general to about 0.001–0.01 volts.

**19. An x-ray study of the structure of electrets.** MAURICE EWING, *University of Pittsburgh, Erie, Pa.*—Electrets were prepared by allowing a molten mixture of rosin, beeswax, and carnauba wax to solidify in a strong electric field, following Adams (Frank. Inst. J. **204**, 469). These were studied by means of a pinhole camera with filtered characteristic radiation from an x-ray tube having a molybdenum target. The patterns obtained all showed three well-defined rings, which indicated spacings of $3.69\pm.02$A, $4.15\pm.02$A, and $4.70\pm.03$A. The 4.15A ring was about three times as intense as the others. When the specimen was set so that the angle between the direction of the x-ray beam and the direction in which the electric field been applied was zero, each circle was of uniform intensity over its entire circumference; but

when this angle was 90°, all circles showed a marked maximum of intensity in the regions in which they would intersect a line drawn through their common center parallel to the direction in which the field had been applied to the specimen.

**20. Modified line in scattered x-rays.** P. A. Ross and J. C. Clark, *Stanford University.* —With balanced metal foils of silver and palladium in a manner previously described, (Proc. Nat. Acad. Sci. Vol. 9, July 1923; J. A. O. S. Vol. 16, June 1928) an attempt has been made to determine the width and structure of the modified $K\alpha_1$, $K\alpha_2$ lines of antimony scattered from beryllium metal. The differences in transmission between equivalent silver and palladium foils were plotted against scattering angle. With sufficiently narrow slits the differences showed clearly the passage, first of $\alpha_2$ and then of $\alpha_1$ past the silver $K$ discontinuity with increasing scattering angle. With present intensity and resolution there is no indication of any step structure or any breadth of line inexplicable by lack of homogeniety of scattering angle in the scattering of antimony $K\alpha_1$, $K\alpha_2$ from beryllium at angles between 55 and 75 degrees.

**21. Apparatus for measuring absorption coefficients of soft x-rays in gases and the absorption in air of the $K_\alpha$ line of carbon.** Elmer Dershem and Marcel Schein, *University of Chicago.*—The apparatus consists of an x-ray tube separated by a celluloid window about $2\times10$ $10^{-4}$ mm thick from a spectrograph into which gases at various pressures may be introduced. Within the spectrograph beams of different wave-length are isolated by means of a ruled grating. The ratio of the intensity of a given spectral line when the spectrograph is filled with gas at a known pressure to the intensity of the line when the spectrograph is exhausted to a high vacuum is measured by a photographic method. Preliminary results for the mass absorption coefficient ($\mu/\rho$) of air have been obtained for the $K_\alpha$ line of carbon ($\lambda=44.6$A). An average of 76 measures yielded the value $\mu/\rho=5350.\pm53$. This probable error of 1 percent compares very favorably with ionization chamber measurements of ordinary x-rays. Extrapolations of any of the various absorption formulae which are known to hold for ordinary x-rays yield values for the absorption coefficients of nitrogen and oxygen which are higher than the above but nevertheless of the same order of magnitude. The investigation is being continued with the use of pure gases and other wave-lengths.

**22. Some measurements of currents thru the walls of x-ray tubes.** Donald P. LeGalley, W. R. Ham, and Marsh W. White, *Pennsylvania State College.*—The walls of a Coolidge water cooled x-ray tube were coated with a thin layer of tin foil. The potential of this coating was varied from that of the anode, to that of the cathode in about 48 equal steps. With the walls, and the anode of the tube, at the same potential, surprisingly large currents were found to be flowing through the glass to the coating. These amounted to as much as 1 m.a., and 2 m.a. in most cases, but were found to be as large as 3 m.a. in some cases. As the potential of the walls was increased from the anode to the cathode, these currents were found to drop off rapidly, become negative, and fall to zero as soon as full retarding potential was reached. A wide range of tube voltages, and tube currents were used. Coating currents were plotted against retarding potentials, and reproducible curves secured, in which breaks occurred at certain retarding potentials time after time. It was found that the average values of these breaks corresponded to the values of the energy levels (in equivalent volts) of the material used in the anode of the tube.

**23. Luminescence due to radioactivity.** D. H. Kabakjian, *University of Pennsylvania.* —Results of several investigations on the nature and decay of luminescence due to radioactivity carried on under the direction of the author are reviewed. It is shown that the rise and decay of luminescence in various compounds, including phosphorescent zinc sulphide, cannot be explained on Rutherford's theory of "active centres." The observed facts can be explained qualitatively by assuming that the alpha, beta and gamma-rays produce excited molecules in the luminescent material. Return of these molecules to their initial state of more stable equilibrium results in emission of luminous energy. The rate at which this return takes place depends upon the thermal agitation of the molecules. The decay of luminescence is explained as due, not to the destruction of the hypothetical active centres, but to the gradual increase of the

absorption constant of the material for the light emitted, as evidenced by its discoloration. The disturbances produced by the exciting rays resulting in discoloration are more stable at ordinary room temperatures than those giving rise to luminescence but not necessarily so at higher temperatures. When a compound whose luminescence has decayed is brought to a temperature which removes discoloration it usually recovers its initial brightness.

**24. The average life for ionized helium.** LOUIS R. MAXWELL, *Bartol Research Foundation.*—The average life $T_{n,l}$ in energy states of ionized helium have been computed for levels up to $n=6$ by calculating all the transition probabilities from the level concerned. The transition probabilities can be obtained directly from known values of the (matrix amplitude)$^2$ as evaluated by the eigenfunctions for an electron in a Coulomb field. $T_{n,1}$ was found to increase proportional to $n^3$ starting with the extremely short time of $1.0\text{x}10^{-10}$ sec. for $n=2$. For other $l$ values this relationship does not always hold but in general $T_{n,l}$ becomes greater for the higher states. $T_n$ (an average mean life, $l$ not specified) has the calculated value of $1.3\text{x}10^{-10}$ sec. for $n=2$ which increases to $1.2\text{x}10^{-8}$ sec. for $n=6$. The method for measuring mean lives previously described by the writer (Phys. Rev. **32,** 721, (1928)) has been applied to the 4686 series of He II. The displacements were found to become progressively greater in going from the lines 4686 (4→3) and 3203 (5→3) to 2733(6→3) and to 2511 (7→3). Assuming that the excited helium ion is produced at a single collision then the lines exhibiting the greater shift must represent longer mean lives, which indicates that the average life becomes greater for the outer levels, in agreement with the theory. The above assumption has been substantiated for the line 4686 from intensity-current measurements.

**25. The incomplete partial Paschen-Back effect in copper.** J. B. GREEN, *Ohio State University.*—The study of the partial Paschen-Back effect in most elements has been limited to the cases in which the multiplet separation is very small compared with the normal Zeeman separation. Darwin has calculated the Zeeman effect for cases in which the magnetic separation varies from 0 to $\infty$. His formulas have been applied to Back's measurements on the $^2P^2D$ multiplet of Cu, 5220, 5218, and 5153. These lines, while they show the ordinary characteristics for low fields, have distortions which are due to the small value of the $^2D$ separation 6.90 cm$^{-1}$ compared with the Zeeman splitting 1.74 cm$^{-1}$. The wave-lengths calculated on Darwin's theory are in almost complete agreement with experiment. The calculated intensities cannot be compared since the observed intensities are only estimated, but they show qualitative agreement with experiment.

**26. Interference measurements in the first spectra of krypton and xenon.** C. J. HUMPHREYS, *Bureau of Standards.*—The wave-lengths of the stronger arc lines of krypton and xenon have been redetermined by the use of fixed etalons. The secondary standards of neon, photographed simultaneously with the spectrum under investigation, were used as a comparison. A sufficient number of krypton lines have been examined to permit fixing the relative values of the $1s$ terms and all the $2p$ and $3p$ terms. The accuracy of the term values is such that the average deviation of calculated combinations from the observed wave-numbers is one part in twenty million. The exact location of the combinations in the infrared region not photographically accessible can now be predicted with certainty. Such lines should prove useful wave-length standards for the infrared region. Further work is contemplated in the examination of the lines for hyperfine structure. It is apparent however from the extremely small variations of the term differences that the intensity of any satellites is too low to affect the wave-lengths. For the two strongest lines in the visible krypton spectrum, for which Perard at the International Bureau obtained wave-lengths 5570.2892 and 5870.9154A., we obtain 5570.2890 and 5870.9153A.

**27. Spark spectrum of rhodium.** A. G. SHENSTONE, *Princeton University.* In the first spark spectrum of rhodium the following terms have been found: for the low structures, $4d^75s$, $^5F$, $^3F$, $^5P$; among the intermediate configurations $4d^75p$, $^5F$, $^5D$, $^5G$, $^3F$, $^3D$, $^3G$, $^5D$, $^5P$, $^5S$. A number of as yet unidentified levels have also been discovered in the low and middle group. The interval rule holds reasonably well for the low $^5F$ and $^3F$, but not at all for the other multi-

plets. All are inverted, except the higher $^5D$ from $d^7p$, which is reinverted, and $^5F$ from the same structure which is partially reinverted. Preliminary investigation of the Zeeman effect indicates that the $g$-values do not coincide with the Landé predictions. Intensities in the multiplets show the same type of irregularity as occurs in the cobalt spark spectrum.

**28. The structure of an emission line.** FRANK C. HOYT, *University of Chicago.* The structure of an emission line within the frequency range of its natural width is calculated on the basis of Dirac's radiation theory as modified by Weyl. It is necessary to make use of a solution of the perturbation equations which is valid for a time long compared to the life-time of the excited state, which is in accord with the uncertainty principle. The result obtained is that the spectral distribution is that for a classical oscillator with damping constant $\frac{1}{2}A$, where $A$ is the sum of the probabilities of spontaneous transition from the upper level to all states of lower energy.

**29. Absorption and collision broadening of the mercury resonance line.** M. W. ZEMANSKY, *National Research Fellow, Princeton University.*—With the assumptions that: (1) the half-breadth of the emission line $\Delta\nu_E$ from a resonance lamp is always greater than that of the absorption line, and depends on the vapor density, geometry, and the exciting line; (2) the half-breadth of the absorption line $\Delta\nu_D$ at low pressures and without any foreign gas is the Doppler breadth; (3) all five components of the λ2537 line of mercury are alike both in emission and in absorption;—the absorption for thickness $l$ is calculated as a function of $k(\nu_0)l$ and $\Delta\nu_E/\Delta\nu_D$, where $k(\nu_0)$ is the absorption coefficient for the center of any one of the components. From experimental values, $k(\nu_0)$ is found to be $1.41\text{x}10^{-13}$ $N$ where $N$ is the number of atoms per cc, and $\Delta\nu_E/\Delta\nu_D$ is 1.21 in these experiments, 1.46 in Orthmann's, 1.50 in Hughes and Thomas', 1.15 in Kunze's and 1.15 in Kopfermann and Tietze's. The absorption coefficient in the presence of a foreign gas is calculated as a function of the frequency and of $\Delta\nu_C/\Delta\nu_D$ where $\Delta\nu_C$ is the Lorentz collision breadth, and the absorption is calculated as a function of $\Delta\nu_C/\Delta\nu_D$ for the values of $k(\nu_0)l$ and $\Delta\nu_E/\Delta\nu_D$ that hold in these experiments and in those of Orthmann. From experimental values of the absorption of mercury vapor in the presence of $H_2$, $N_2$, A, and CO, $\Delta\nu_C$ is found as a function of pressure for each gas. From these curves the effective cross-section is found to be smallest for those gases which quench mercury resonance radiation the most.

**30. Energy distribution in the ultraviolet spectrum of skylight.** BRIAN O'BRIEN, *J. N. Adam Hospital, Perrysburg, N. Y.*—Energy distribution in the spectrum of sunlight scattered from the sky was measured by a method previously described (Phys. Rev. **33,** 640 (1929)) from λ4000A to λ3010A and compared to energy distribution in the direct solar beam. For very clear sky the ratio of intensity of sky, 60° from sun 30° from zenith, to intensity of sun is proportional to $1/\lambda^4$ over the above wave-length range. For sky uniformly cloudy showing faint blurr of sun, above ratio is nearly independent of λ, and energy distribution in direct solar beam agrees with that measured on very clear days for the same elevation of sun, even when absolute intensity in direct beam is reduced by clouds to 1/100 that on a clear day. For hazy or slightly cloudy skys ratio of sky intensity to sun intensity increases with decrease in λ but less rapidly than $1/\lambda^4$, the scattering being made up of a molecular and a non-selective term. The values for the energy distribution in the spectrum of direct clear day sunlight from λ3300A to λ2903A previously reported, (Phys. Rev. **33,** 1072 (1929)) (J.O.S.A. **20,** 150 (1930)), are thus applicable to sunlight through clouds or haze or scattered by clear or cloudy sky, providing the character of the scattering is taken into account. These results require that both non-selective and molecular scattering occur below the layer of atmospheric ozone, in agreement with accepted values for the height of this layer.

## SUPPLEMENTARY PROGRAM

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